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ELECTROSTIMULATION OF MUSCLES AS A METHOD FOR THE TREATMENT AND PROPHYLAXIS OF HEMODYNAMIC DISTURBANCES DURING PROLONGED HYPOKINESIA

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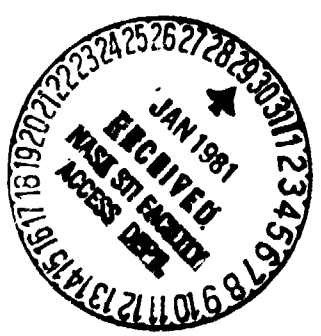
Translation of "Elektrostymulyatsiya m'yaziv yak metod likuvannya i profilaktyky porushen' gemodynamiky pry tryvaliy gipokineziyi," Visnykh Akademii Nauk URSR, No. 10, 1979, pp. 48-54



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16. Abstract The effect of electrostimulation of muscles was studied on surgical tuberculosis patients, after 1-24 months of bed rest as a model of prolonged hypokinesia, on the central hemodynamics and peripheral circulation. Hemodynamic and peripheral circulation indices were recorded before, at the end of and 5 days after 10 days of electrostimulation for 45 min daily, at rest and after a physical loading test. It was found that stroke and minute volume, cardiac output and regional circulation improve and heart rate and peripheral resistance decrease and, thus, that the functional state of the cardiac muscle and vascular tone are improved by electrostimulation of selected groups of skeletal muscles.

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Ye.O. Dukhin and L.Y. Zhukovs'kyy

The nature of many diseases and their treatment requires a prolonged stay in bed with reduced muscle activity (hypokinesia). The circulatory changes which develop in this case have not been dealt with sufficiently fully in the literature. /481*

Our previous studies [1, 2] showed that, in healthy persons who voluntarily underwent hypokinesia and surgical tuberculosis patients, prolonged hypokinesia leads to numerous changes in the central hemodynamics and regional circulation, which indicate that the reserve capabilities of the cardiovascular system are depleted.

Questions of the prophylaxis and treatment of systemic disorders which develop in the body during hypokinesia have been studied insufficiently. The use of a set of physical exercises and a number of pharmacological agents for the prophylaxis and treatment of "hypokinetic disease" are not always sufficiently effective [3-5].

We were the first to apply electrostimulation of the muscles (back, thigh, tibia). The studies conducted showed that electrostimulation of the muscles of healthy persons who voluntarily underwent hypokinesia produces a conditioning effect on the circulatory system and greatly mitigates the unfavorable effects of hypokinesia on the hemodynamics [1]. On consideration that the changes in hemodynamics of healthy persons and persons in prolonged hypokinesia are of a primarily uniform nature, we thought it possible to take advantage of muscle electrostimulation of surgical tuberculosis patients.

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*Numbers in the margin indicate pagination in the foreign text.

A total of 53 persons from 17 to 50 years old were studied. Of them, 10 had lesions of the knee joint, 13, of the hip, and 30 had tuberculous spondylitis, without symptoms of lesions of the spinal cord or functions of the pelvic organs. Persons without symptoms of specific intoxication were selected. Immobilization forced them to be in bed, whic favored the selection of surgical tuberculosis as a model of hypokinesia of varied duration. During bed rest, the people were divided into three groups: the first included people with 1-5 months hypokinesia (23 persons); the second, 6-12 months (16 persons); the third, 13-24 months (14 persons). Despite the arbitrariness of the times we selected, they make it possible to observe and compare changes in hemodynamics during hypokinesia of varied duration.

Electrostimulation of the muscles was carried out by means of an 8 channel PMS-2 apparatus, developed at the Kiev Laboratory, Institute of Biomedical Problems, USSR Ministry of Public Health. The characteristic features of the equipment are: every channel of the electrostimulator provides independent alternation of periods of muscle contraction and relaxation, with a controlled 2-4 sec recurrence frequency. The channels were electrically connected together, and they were divided into groups of 4 each. Phase shifting of the output signal between groups was regulated between 20° and 180°. With a 180° phase shift, the contraction period of one group of muscles corresponds to the relaxation period of another. This results in coordinated action of antagonist muscle groups. The output signal is of a form similar to that of the action potential. The output casacade of each channel is a current generator, with a regulated pulse amplitude from 0 to 60 mA. Pulse duration is 1 msec. Selected amplitude-frequency modulation unification ensures great electrostimulation comfort and effect.

Electrostimulation was carried out for 45 minutes daily for 10 days. To evaluate the hemodynamic effectiveness of stimulation, rheography with the application of calculation coefficients [6] and oscillography were used. This made it possible to determine these indices: minute volume (MV); stroke volume (SV); heart rate (HR); systolic (SAP), diastolic (DAP) and average (AAP) arterial pressure; pulse blood flow in the vessels of the muscles (PBFm) and brain (PBFb).

The total peripheral resistance (TPR) and the left ventricle output index (LVOI) were determined by calculation.

All the indices studied were determined at the beginning of the 10 day electrostimulation period, on day 10 of electrostimulation and on the fifth day of the recovery period.

The changes in the central hemodynamics and regional circulation indices as a result of electrostimulation of the muscle of the surgical tuberculosis patients in hypokinesia of varied duration are presented in the table.

It was found that the minute volume of blood of the group 1 patients was practically unchanged on electrostimulation day 10, while the cardiac output of groups 2 and 3 increased by 5.3 and 10.7%, respectively. In this case, some decrease in total peripheral resistance was found, especially in the group 3 patients, while the average arterial pressure remained at the initial level, with some tendency to decrease among the group 3 patients (Fig. 1). /50

The data presented indicate that, as a result of electrostimulation, the cardiac output increases, and the total peripheral resistance decreases. The changes in hemodynamics of the patients were most pronounced immediately after the end of electrostimulation (1-2 minutes later), while the minute volume of blood frequently increased by 20-30% and the average arterial pressure was 10-15% above the initial value. /51

On day 5 of the recovery period, the central hemodynamics indices studied approached the initial level, however, they did not reach it. The result of this is that the effects of muscle electrostimulation are found several days after it ends.

Data on changes in the minute and stroke volumes and heart rates of patients at various times of prolonged hypokinesia, as a result of electrostimulation of muscles, are presented in Fig. 2. As is evident from the figure, the stroke volume of blood increased approximately the same (by 6-7%) in all three groups on day 10 of the electro- /52

CENTRAL HEMODYNAMICS AND REGIONAL CIRCULATION INDICES AND THEIR CHANGES IN HYPOKINESIA OF VARIED DURATION

a Длительность гипокинезии	b Статистические показания	c Гемодинамические показатели	d УОК, n мл	e ЧСС, o уд/мин	f ХОК, p л/мин	g САТ, q мм рт. ст.
t 1—5 мес. n=20	u Вначале	M_1	73,6	73	5,37	147,4
		$\pm m_1$	2,4	0,9	0,15	3,1
	v 10 дней электростимуляции	M_2	77,5	70,3	5,45	142,7
		$\pm m_2$	2,7	1,1	0,17	3,4
		M_2-M_1%	+5,4	−3,8	+1,6	−3,3
		P	<0,3>0,2	<0,05>0,02	>0,5	>0,5
	w 5 дней восстановления	M_3	78,1	70,0	5,48	142,9
		$\pm m_3$	2,3	1,0	0,16	3,2
		M_3-M_1%	+6,3	−4,2	−2,0	−3,2
		P	<0,2>0,01	<0,02>0,01	<0,5>0,2	>0,5
t 6—12 мес. n=16	u Вначале	M_4	69,5	71	4,93	131,8
		$\pm m_4$	2,5	1,0	0,18	2,9
	v 10 дней электростимуляции	M_5	75,3	68,8	5,19	126,9
		$\pm m_5$	2,7	1,2	0,21	3,2
		M_5-M_4%	+8,4	−3,1	+5,3	−3,4
		P	<0,2>0,1	<0,1>0,05	<0,5>0,2	>0,5
	w 5 дней восстановления	M_6	73,8	69,4	5,12	130,1
		$\pm m_6$	2,7	1,0	0,18	3,3
		M_6-M_4%	+6,2%	−2,3	+3,9	−1,4
		P	<0,5>0,2	<0,2>0,1	<0,5>0,2	>0,5
t 13—24 мес. n=14	u Вначале	M_7	62,1	67	4,16	119,4
		$\pm m_7$	2,5	1,0	0,17	3,1
	v 10 дней электростимуляции	M_8	66,5	69,3	4,61	123,8
		$\pm m_8$	1,9	1,3	0,14	3,1
		M_8-M_7%	+7,0	+3,4	+10,7	+3,7
		P	<0,2>0,1	<0,2>0,1	=0,05	>0,5
	w 5 дней восстановления	M_9	63,8	67	4,26	122,5
		$\pm m_9$	2,2	1,2	0,16	2,9
		M_9-M_7%	+2,4	0	+2,4	+2,6
		P	>0,5		>0,5	>0,5

Key:
a. Duration of hypokinesia
b. Statistical index
c. Hemodynamic index
d. Stroke volume
e. Heart rate
f. Minute volume
g. Systolic arterial pressure
h. Average arterial pressure
i. Diastolic arterial pressure
j. Total peripheral pressure
k. Left ventrical output index
l. Muscle vessel pulse flow
m. Brain vessel pulse flow
n. ml
o. Rate/min
p. Liter/min
q. mm Hg
r. Dyne·sec^{-5}·cm
s. Rheographic index
t. Months
u. Initial
v. Electrostimulation day 10
w. Recovery day 5

DUE TO ELECTROSTIMULATION OF MUSCLES OF SURGICAL TUBERCULOSIS PATIENTS

h	i	j	k	l	mm
q	q	r		s	s
102,1 2,5	80,5 1,8	1503 31	4,16 0,07	0,137 0,012	0,101 0,005
100,5 2,7 −1,9 >0,5	76,4 2,1 −5,1 <0,2>0,1	1476 33 −1,8 >0,5	4,34 0,06 +4,0 −0,5	0,145 0,01 +5,8 >0,5	0,128 0,006 +21,7 <0,02>0,01
101,5 2,6 −1,6 >0,5	78,1 1,9 −3,1 >0,5	1480 37 −1,4 >0,5	4,42 0,06 +6,2 −0,2>0,1	0,139 0,012 +1,4 >0,5	0,117 0,007 +15,7 <0,01>0,05
89,5 2,3	79,5 1,7	1451 32	3,68 0,08	0,119 0,009	0,097 0,007
89,4 2,4 0	75,7 1,9 −4,8 <0,5>0,2	1381 32 −4,8 <0,5>0,2	3,86 0,07 +4,8 <0,2>0,1	0,135 0,01 +13,4 <0,5>0,2	0,116 0,008 +8,4 <0,2>0,1
90,8 2,1 +1,4 >0,5	77,7 1,9 −2,3 >0,5	1418 36 −5,6 >0,5	3,79 0,08 +3,0 <0,5>0,2	0,119 0,009 0	0,11 0,008 +3,4 <0,2>0,1
81,1 2,0	76,4 1,5	1557 37	2,93 0,07	0,112 0,011	0,098 0,007
83,7 2,3 +3,2 <0,5>0,2	72,7 1,7 −4,8 <0,2>0,1	1438 44 −7,6 <0,1>0,05	4,21 0,08 +9,5 <0,05>0,02	0,123 0,01 +9,0 >0,5	0,124 0,006 +26,5 <0,2>0,01
79,1 2,2 −2,5 >0,5	73,1 1,7 −4,3 <0,5>0,2	1483 35 −4,7 <0,5>0,2	3,97 0,09 +1,0 >0,5	0,118 0,01 +5,4 >0,5	0,124 0,06 +26,5 <0,02>0,01

stimulation period. In this case, the heart rate increased (by 3.4%) for group 3. This kind of interrelation of the stroke volume and heart rate stipulates a higher level of the minute volume for group 3 patients than the heart output in groups 1 and 2.

It also was found that, immediately after stopping electrostimu-

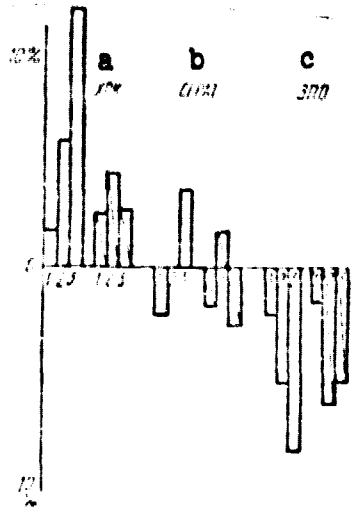

Fig. 1. Central hemodynamics indices and their changes as a result of electrostimulation of muscles of patients in hypokinesia of varied duration. Conventional symbols: open bars, indices on day 10 of electrostimulation; diagonal lined bars, on day 5 of recovery period; 0, indices at start of electrostimulation period; figures under bars indicate patient groups with different durations of hypokinesia period.

Key: a. Minute volume of blood
b. Average arterial pressure
c. Total peripheral resistance

lation, the stroke volume and heart rate exceeded the initial level by 20-30%, and the increase in minute volume occurred primarily because of the increase in heart rate (especially for the group 2 and 3 patients). This kind of change of stroke volume and heart rate was observed on electrostimulation days 1-3. On days 4-10, the increase in minute volume of the group 1 and 2 patients was accompanied primarily by an increase in stroke volume, while the increased minute volume level of the group 3 patients occurred due to the heart rate.

Five days after the end of the electrostimulation period, the stroke volume of the group 1 and 2 patients remained elevated, and that of the group 3 patients approached the initial values. The minute volume also exceeded the initial level, and the heart rate was somewhat reduced, especially for group 1.

Electrostimulation led to an increase in the work performed by the heart (Fig. 2). The most evident changes were found in the group 3 patients (+9.5%). However, on recovery day 5, the left ventricle output index of the group 3 patients was scarcely above the initial value, while that of the group 1 and 2 patients was higher (+6.2 and +3.0%, respectively).

There is interest in analysis of the systolic, average and diastolic arterial pressures (Table). Electrostimulation results in a 4-6% decrease in diastolic arterial pressure, and the disturbance was noted 5 days after ending use of the method we have described. A tendency /

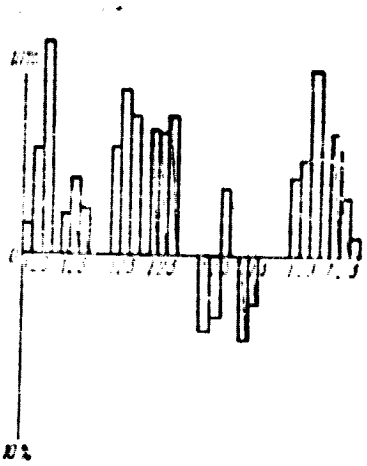

Fig. 2. Cardiac output, heart rate, left ventricle output indices and their changes as a result of electrostimulation of muscles of patients in hypokinesia of varied duration; conventional symbols same as in Fig. 1.

towards a decrease in systolic and average arterial pressure also was noted in the group 3 patients on day 10 of the electrostimulation period. However, on day 5 of the recovery period, the systolic and average arterial pressure of the group 3 patients was reduced.

The data presented in Fig. 3 characterize the change in pulse blood filling of the brain vessels and skeletal muscle vessels in hypokinesia of varied duration, combined with electrostimulation. As is evident from the figure, on day 10 of the electrostimulation period, the blood filling of the brain vessels was noticeably higher than initially, especially in the group 1 and 3 patients (Table), by 21.7 and 26.5%, respectively. On day 5 after stopping electrostimulation, the indices studied were increased.

The pulse blood filling of the muscle vessels as a result of electrostimulation also increased. Thus, on day 10 of the electrostimulation period, the indices studied, compared with the initial values, increased by 5.8% in group 1 patients, 13.4% in group 2 patients and 9.0% in group 3 patients. On the fifth day of the recovery period, only those of the group 3 patients remained slightly elevated (by 5.4%).

Data on the minute and stroke volumes of blood and heart rate as a result of electrostimulation of patients at various times in hypokinesia, in the first minute of recovery after a physical loading test (lifting two 1 kilogram dumbbells for 3 minutes, at a rate of 30 times per minute), are presented in Fig. 4. An increase in stroke volume and heart rate of all patients in response to physical loading was noted. However, the correlation of these indices and their specific weight in producing the minute volume of blood at the start of the electrostimulation period is irregular, for patients at different

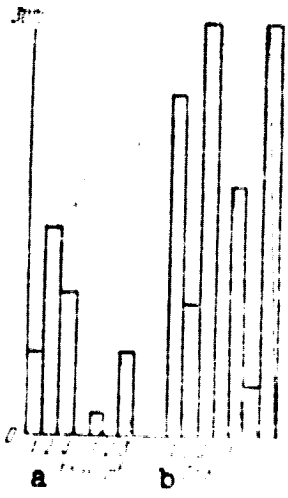

Fig. 3. Regional circulation indices and their changes as a result of electrostimulation of muscles of patients in hypokinesia of varied duration; conventional symbols same as in Fig. 1.

Key: a. Pulse blood filling of muscle vessels
b. Pulse blood filling of brain vessels

times of hypokinesia. The longer the bed rest, the greater the role of the heart rate and the less pronounced the changes in stroke volume in producing the minute volume of blood. On day 10 of electrostimulation, an increase in stroke volume and heart rate of all patients also is noted in response to physical loading. In this case, the increase in minute volume of the group 1 and 2 patients was accompanied by a more substantial increase in stroke volume than in heart rate, which can be attributed to the conditioning effect of electrostimulation on the cardiac muscle.

It was found from the studies conducted that prolonged hypokinesia causes disturbances of the central hemodynamics and regional circulation, and that the extent of their change depends on the duration of bed rest. Under these conditions, the functional state of the cardiac muscle deteriorates most clearly. It is manifested by changes in the correlation of the stroke volume of blood and heart rate indices: a decrease in stroke volume and an increase in heart rate. Electrostimulation of the muscles of the patients we observed resulted in an increase in minute volume, stroke volume, the work of the cardiac muscle and the regional circulation, and some decrease in the total peripheral resistance and a reduction in heart rate. As a result of electrostimulation, the functional state of the cardiac muscle improved, which was expressed most distinctly in physical loading studies, and leveling off of the hemodynamic indices between groups of patients at various times in hypokinesia was noted.

The studies of a number of authors indicate that short term hypokinesia leads to a decrease in tone of the sympathetic portion of the central nervous system [3, 7 et al] and a decrease in volume of

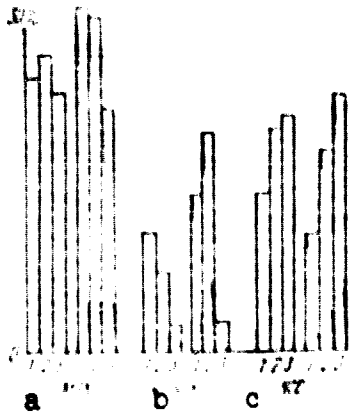

Fig. 4. Cardiac output, heart rate indices and their changes as a result of electrostimulation of muscles of patients in hypokinesia of varied duration with physical loading; 0 is output index before physical loading test; remaining conventional symbols as in Fig. 1.

Key: a. Minute volume of blood
b. Stroke volume of blood
c. Heart rate

circulating blood [8, 9 et al]. It is evident that, in many months of hypokinesia, the role of these factors in the regulatory mechanisms of the circulatory system increases, particularly against the background of decreases in the energy demands of the body tissues [10]. This may be the basis of the changes in cardiac output and vascular tone of the patients we studied. It can be presumed that electrostimulation in prolonged hypokinesia results in some restoration of the tone of the central nervous system and volume of circulating blood and an increase in the energy demands of the tissues, which evidently explains the increase in functional state of the circulatory system of patients by this effect. /54

Thus, electrostimulation of muscles contributes to recovery from disturbances of the hemodynamics in prolonged hypokinesia, and it can be recommended for use in the clinic, as a means of treatment of "hypokinetic disease."

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